LONG RANGE CORRELATIONS;EVENT SIMULATION AND PARTON PERCOLATION

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Introduction to long range correlations

STAR data and string like models

Clustering of color sources

Scales of pp and Pb Pb collisions

Similarities between CGC and percolation

Results on b for pp and AA

Conclusions

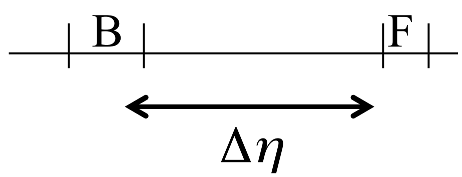
LONG RANGE CORRELATIONS

• A measurement of such correlations is the backward–forward dispersion

$$D^2_{FB} = <n_B\, n_F> - <n_B><n_F>$$

where $n_B(n_F)$ is the number of particles in a backward (forward) rapidity

$$D^2_{FB} = <N>\left(<n_{1B}n_{1F}> - <n_{1B}><n_{1F}>\right) + \left(<N^2> - <N>^2\right)<n_{1F}><n_{1B}>$$



$<N>$ number of collisions: $<n_{1B}>$,$<n_{1F}>$ F and B multiplicities in one collision

• In a superposition of independent sources model, D^2_{BF} is proportional to the fluctuations(D^2_N)on the number of independent sources (It is assumed that Forward and backward are defined in such a way that there is a rapidity window $\Delta_\eta \geq 1.0$ to eliminate short range correlations).

Correlation parameter

$$< n_B >= a + b n_F$$

with

$$b \equiv D_{BF}^2 / D_{FF}^2$$

- b in pp increases with energy. In hA increases with A also in AA,increases with centrality

The dependence of b with rapidity gap is quite interesting, remaining flat for large values of the rapidity window.

Existence of long rapidity correlations at high density

Correlation Parameter b

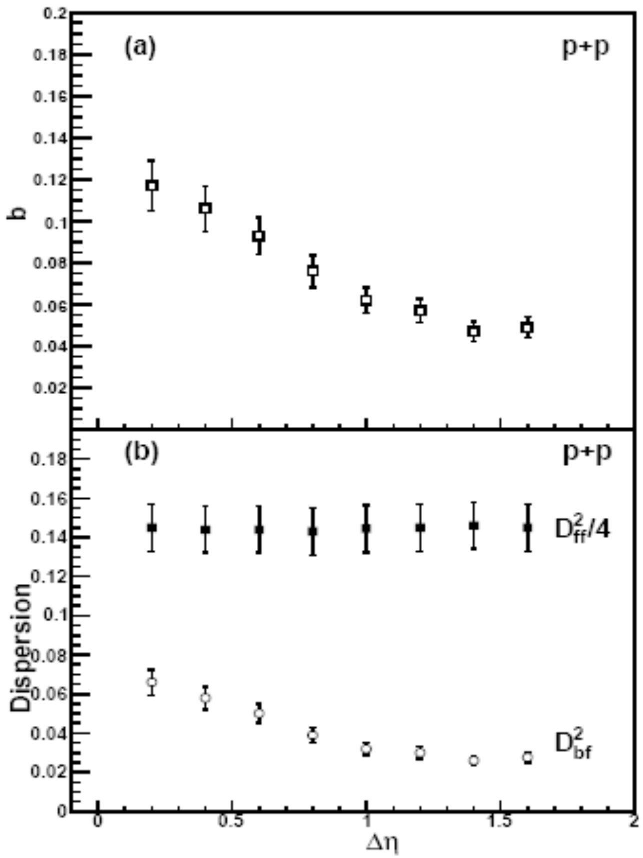
I Situation: Symmetrica

:

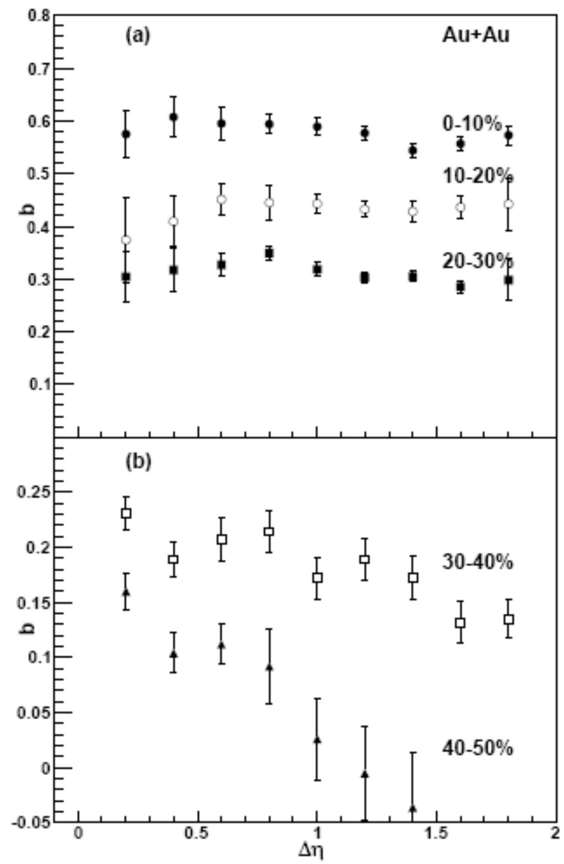
$$\boxed{b \equiv \frac{1}{1 + \frac{K}{<n_F>}}}$$

- 1/K is the squared normalized fluctuations on effective number of strings(clusters)contributing to both forward and backward intervals

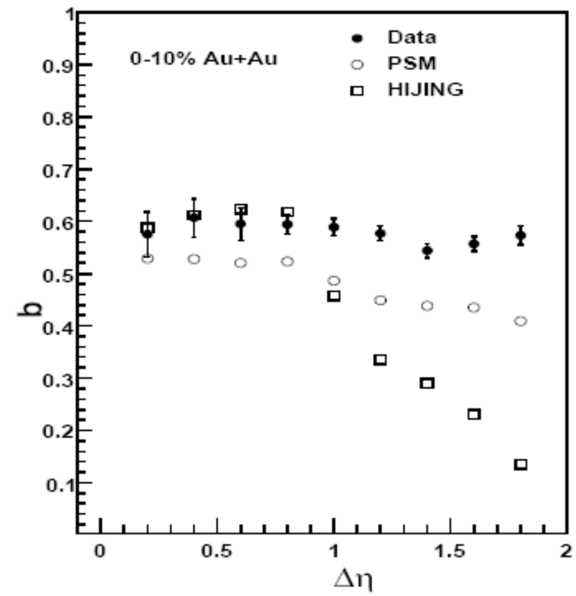
The heigth of the ridge structure is proportional to n/k



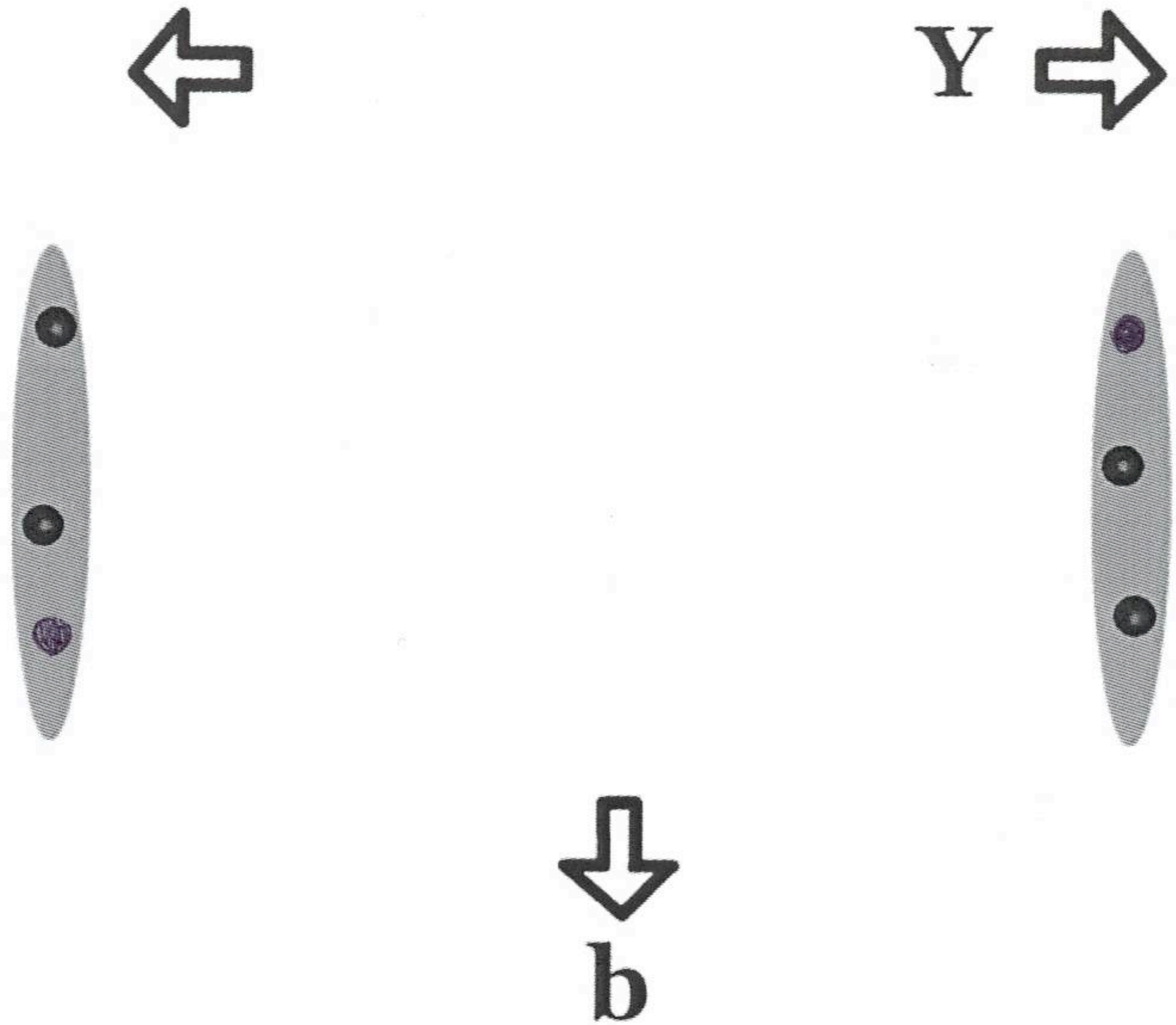
(a)
p+p
b
(b)
p+p
Dispersion
$D_{ff}^2/4$
D_{bf}^2
Δη

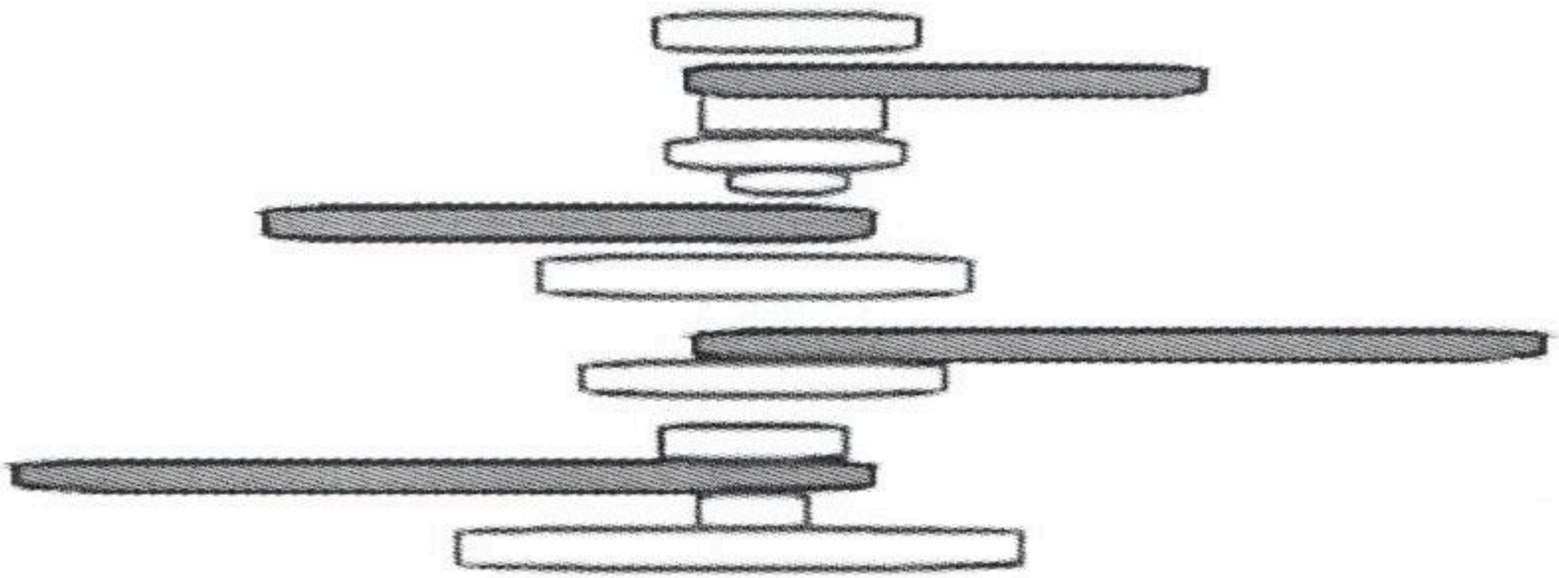


(a)
Au+Au
0-10%
10-20%
20-30%
b
(b)
30-40%
40-50%
b
Δη



0-10% Au+Au
Data
PSM
HIJING
b
Δη


Y
b



--The strings must be extended in both hemispheres,otherwise either they do not obtained LRC(Heijing)or they have to include parton interactions(PACIAE).PACIAE reproduces well b for central but not for peripheral

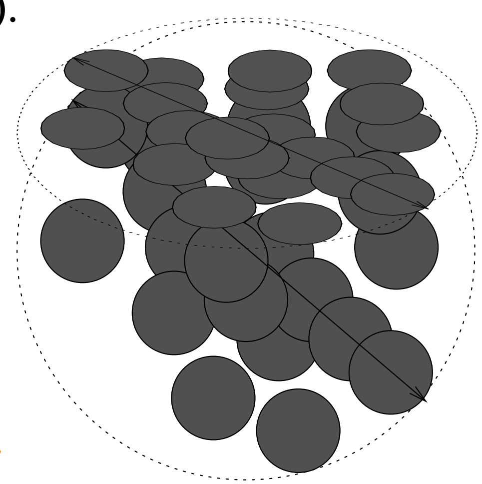
--Without parton interactions the length of the LRC is the same in pp than AA(modified wounded model of Bzdak)

CLUSTERING OF COLOR SOURCES

- Color strings are stretched between the projectile and target
- Strings = Particle sources: particles are created via sea qqbar production in the field of the string
- Color strings = Small areas in the transverse space filled with color field created by the colliding partons
- With growing energy and/or atomic number of colliding particles, the number of sources grows
- So the elementary color sources start to overlap, forming clusters, very much like disk in the 2-dimensional percolation theory
- In particular, at a certain critical density, a macroscopic cluster appears, which marks the percolation phase transition

(N. Armesto et al., PRL77 (96); J.Dias de Deus et al., PLB491 (00); M. Nardi and H. Satz(98).

• How?: Strings fuse forming clusters. At a certain critical density η_c (central PbPb at SPS, central AgAg at RHIC, central pp at LHC) a macroscopic cluster appears which marks the percolation phase transition (second order, non thermal).



Transverse density

$$\eta = N_{st}\frac{S_1}{S_A}\ , \quad S_1 = \pi r_0^2, \quad r_0 = 0.2 \ \text{ fm}, \quad \eta_c = 1.1 \div 1.2.$$

• Hypothesis: clusters of overlapping strings are the sources of particle production, and central multiplicities and transverse momentum distributions are little affected by rescattering.

Particle density from string cluster

$$\mu_n = \sqrt{\frac{nS_n}{S_1}}\mu_1 \; ; \; < p_T^2 >_n = \sqrt{\frac{nS_1}{S_n}} < p_T^2 >_1$$

Energy-momentum of the cluster is the sum of the energy-momemtum of each string. As the individual color field of the individual string may be oriented in an arbitrary manner respective to one another, $Q_n^2 = nQ_1^2$

- At high densities

  - $< \mu >_n = nF(\eta) < \mu >_1 \quad < p_T^2 >_n = \frac{< p_T^2 >_1}{F(\eta)}$
  - $F(\eta) = \sqrt{\frac{1-e^{-\eta}}{\eta}}, \; \eta = N_S \frac{\pi r_0^2}{S_A}$
  - r_0 is the transverse size of a single string $\simeq$ 0.2 fm.

- Scales of pp and AA

Why Protons?

In String Percolation…

$$\eta_{AA} = \left(\frac{r}{R}\right)^2 \overline{N}^s \cong \frac{N_A^{4/3}}{N_A^{2/3}}\left(\frac{r}{R_p}\right)^2 \overline{N}_p^s$$

$$\eta_{AA}(s) = N_A^{2/3}\eta_{pp}(s)$$ and $$\overline{N} \sim s^{2/7}$$

$$\eta_{PbPb}(\sqrt{s}) \cong 20GeV - 200Gev$$

$$\eta_c \approx 1.15$$

$$\eta_{PP}(\sqrt{s}) \cong 6TeV - 14Tev$$ ← LHC

Energy momentum conservation
leads to increase in rapidity
(length) of string

Comments

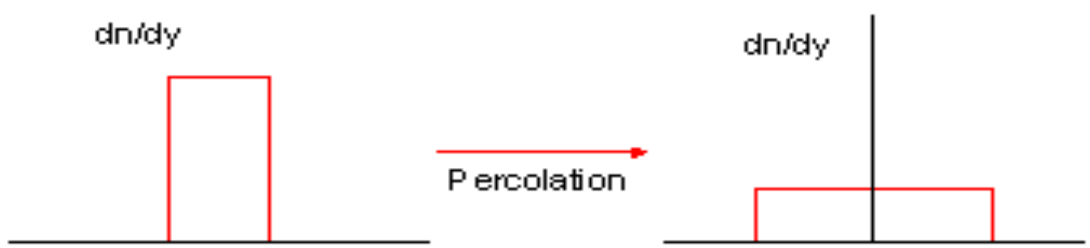
- Data (RHIC)
- FB Correlations YES: SO LONG?

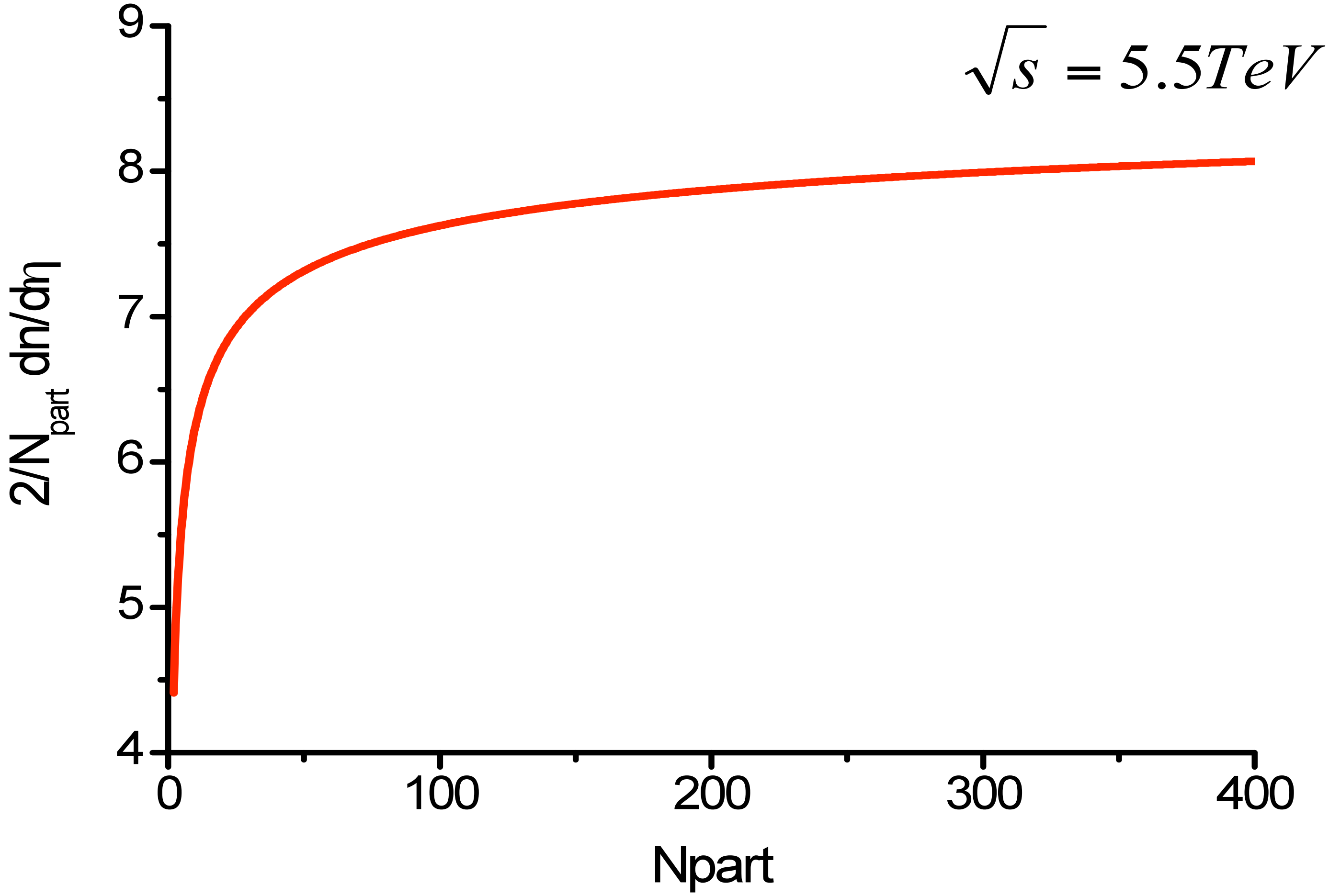
Colour Flux Tube: OK

Strings : TOO SHORT

One String: $x^{+} = x^{-} = x = 1/\sqrt{s} \Rightarrow \Delta y_1$

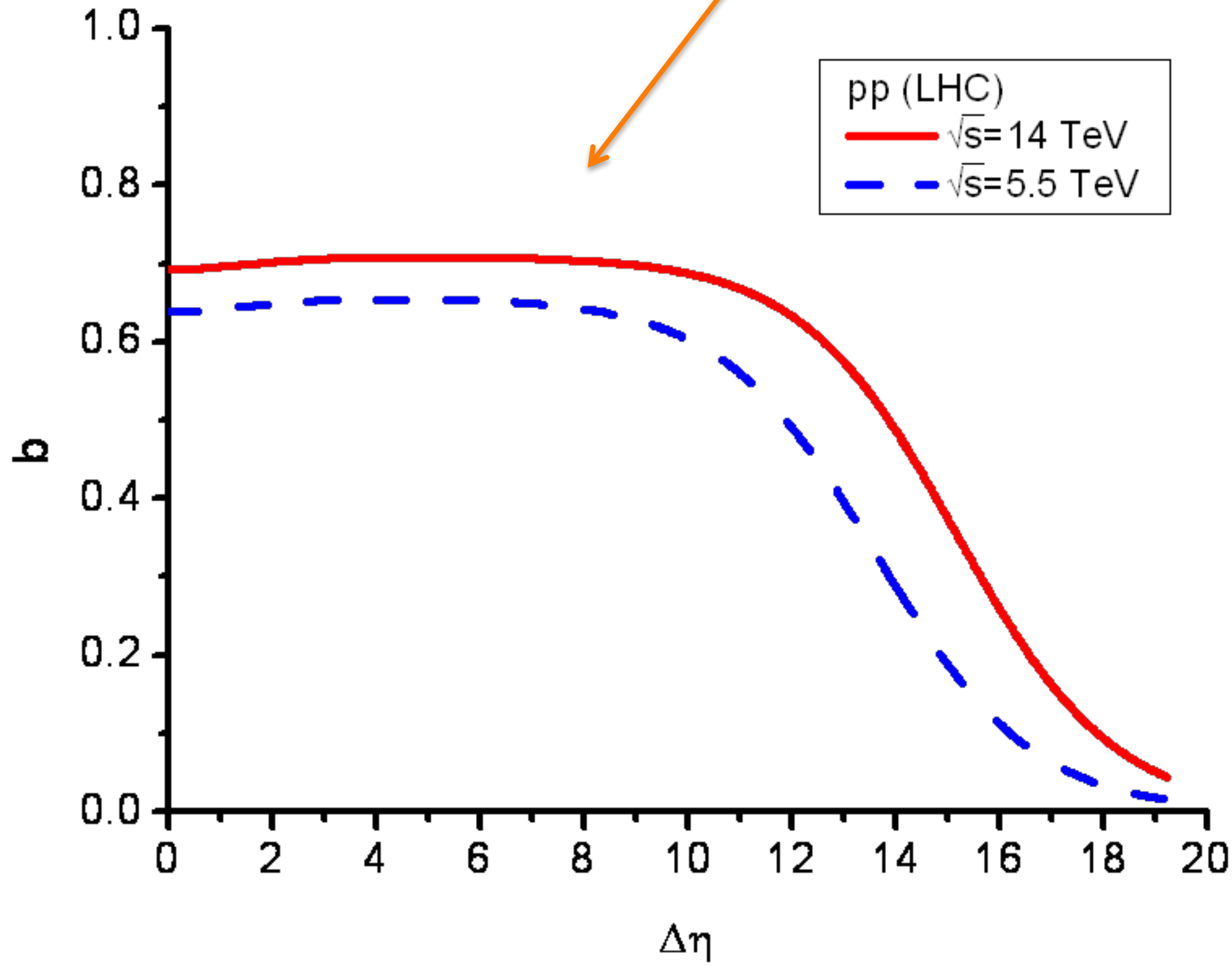
N^s Strings: $\Delta y_{N_s} = \Delta y_1 + 2\ln(N_s)$



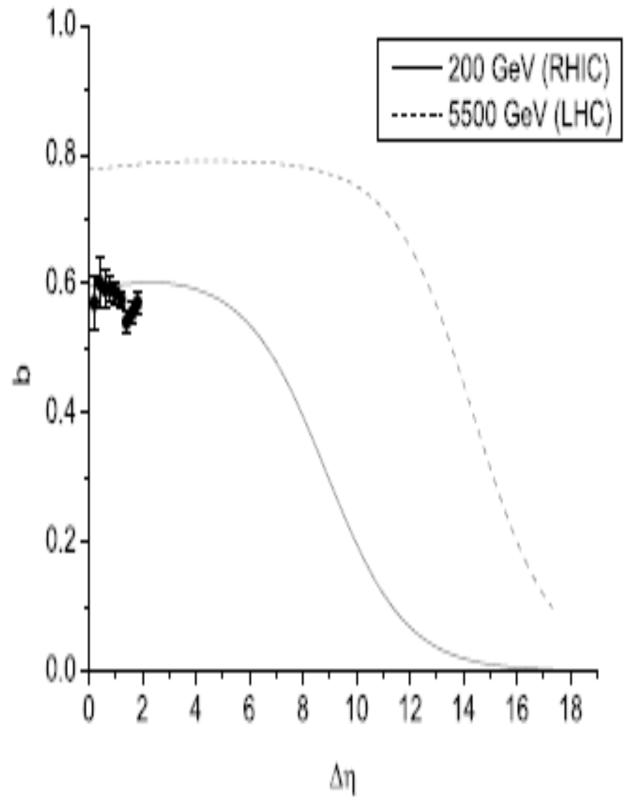


$\sqrt{s} = 5.5TeV$
9
8
7
6
5
4
$2/N_{part}\ dn/d\eta$
0
100
200
300
400
Npart

Very long (falsifiable prediction)



AA



1.0
0.8
0.6
0.4
0.2
0.0
b
0
2
4
6
8
10
12
14
16
18
Δη
200 GeV (RHIC)
5500 GeV (LHC)

Qualitative dictionary PERC-CGC

Transverse size $r_0^2 F(\eta)$

CGC $1/Q_s^2$

Effective number of clusters

$$< N >= \frac{(1-exp(-\eta))R_A^2}{F(\eta)\, r_0^2} = (1-exp(-\eta\ ))^{1/2}\sqrt{\eta}\left(\frac{R_A}{r_0}\right)^2$$

low density $\eta\left(\frac{R_A}{r_0}\right)^2 \ , N_A^{4/3},\ exp(\ 2\lambda\gamma\ )$

high density $\sqrt{\eta}\left(\frac{R_A}{r_0}\right)^2 ,N_A,\ exp(\lambda\gamma\ )$

$$CGC \quad \frac{1}{\alpha_S} R_A^2 Q_S^2 \ ,\ N_A\ ,\ exp(\lambda\gamma\ )$$

rapidity extension

$$\Delta y_N = \Delta y_1 + 2lnN_S \quad , \qquad lnN_A\ ,\ ln\ s$$

$$CGC \quad \frac{1}{\alpha_s} \qquad ln\ N_A\ ,\ ln\ s$$

1/k = normalized fluctuation of eff number of strings

$$\kappa = \frac{<N>^2}{<N^2> - <N>^2}$$

low density $\quad k \to \infty$

high density $\quad k \to \infty$

$$k = \frac{<N>}{(1-\exp(-\eta))^{3/2}}$$

high density $\quad \sqrt{\eta}\left(\frac{R_A}{r_0}\right)^2 , N_A , \exp(\lambda\gamma)$

low density $\quad \frac{1}{\sqrt{\eta}}\left(\frac{R_A}{r_0}\right)^2$

CGC $\quad k = R_S^2 Q_s^2 \;, N_A \;, \exp(\lambda\gamma)$

MULTIPLICITY DISTRIBUTIONS

NEGATIVE BINOMIAL

$k = \langle N \rangle k_0$ (k_0, single effective string)

low density $k \to \infty$, $k_0 \to \infty$ Poisson

high density $k \to \infty$, $k_0 \to 1$ Bose-Einstein

$CGC \quad k_o = 1 \quad B{:}E \quad , \quad k = \langle N \rangle$

k first decreases with density (energy)

Above an energy(density) k increases

$\Rightarrow$ Multiplicity distributions (normalized,

i.e. $\langle n \rangle P_n$ as a function of $n / \langle n \rangle$

will be narrower (Quantum Optical prediction)

$$b = \frac{1}{1 + \frac{d}{(1 - e^{-\eta})^{3/2}}}$$

low density $b \longrightarrow 0$

high density (energy) $b \longrightarrow 1/1 + d$

CGC

$$b = \frac{1}{1 + \alpha_S^2 c}$$

high density (energy) $b \longrightarrow 1$

Conclusions

---For pp at LHC are predicted the same phenomena observed at RHIC in Au-Au

---Normalized multiplicity distributions will be narrower

---Long range correlations extended more than 10 units of rapidity at LHC.Large LRC in pp extended several units of rapidity.

---Large similarities between CGC and percolation of strings.Similar predictions corresponding to similar physical picture.Percolation explains the transition low density-high density

a few notes

- Close relation between Glasma and SPM
  - (however) no magnetic fields here
- No fundamental theoretical basis
  - But, clear physical picture and straightforward calculational framework
  - Good testbed for qualitative features